ordinary steam-engine. The mirror is of silvered copper; the boiler is blackened and is surrounded by a glass cylinder, which of course permits the passage of the sun's heat through it, but obstructs its escape after absorption. The whole thing costs 4000 francs, and it could be used in many countries for at least 200 days in the year.

G. F. RODWELL

THE HERRING [1]

IT is now nineteen years since my attention was first specially directed to the natural history of the herring, and to the many important economical and legal questions connected with the herring fisheries. As a member of two successive Royal Commissions, it fell to my lot to take part in inquiries held at every important fishing station in the United Kingdom between the years 1862 and 1865, and to hear all that practical fishermen had to tell about the matter; while I had free access to the official records of the Fishery Boards. Nor did I neglect such opportunities as presented themselves of studying the fish itself, and of determining the scientific value of the terms by which, in the language of fishermen, the various conditions of the herring are distinguished.

Diligent sifting of the body of evidence thus collected and passed under review, led to the satisfactory clearing away in my own mind of some of the obscurities which, at that time, surrounded the natural history of the fish. But many problems remained, the solution of which was not practicable by investigations which, after all, were only incidents in the course of a large inquiry, embracing a vast number of topics beside herrings and herring fisheries; and it is only within the last few years that the labours of the German West Baltic Fishery Commission have made such large additions to the state of our knowledge in 1865, that the history of the herring is brought within measurable distance of completeness.

Considering the vast importance of the herring fisheries of the Eastern Counties, it occurred to me when the President of the National Fishery Exhibition did me the honour to ask me to address you, that nothing could be more likely to interest my audience than a summary statement of what is now really known about a fish which, from a fisherman's point of view, is probably the chief of fishes.

I am aware that I may lay myself open to the application of the proverb about carrying coals to Newcastle, if I commence my observations with a description of the most important distinctive characters of a fish which is so familiar to the majority of my hearers. And perhaps it is as well that I should at once express my belief that most of you are as little likely to mistake a herring for anything else as I am. Nay, I will go further. I have reason to believe that any herring-merchant, in a large way of business, who may be here, knows these fish so much better than I do, that he is able to discriminate a Yarmouth herring from a Scotch herring and both from a Norway herring; a feat which I could not undertake to perform. But then it is possible that I may know some things that he does not. He is very unlike other fishermen and fish-merchants with whom I have met, if he has any but the vaguest notions of the way of life of the fish; or if he has heard anything about those singularities of its organisation which perplex biologists; or if he can say exactly how and why he knows that a herring is not a sprat, a shad, or a pilchard. And all kinds of real knowledge and insight into the facts of nature do so bear upon one another and turn out in strange ways practically helpful, that I propose to pour out my scientific budget, in the hope that something more may come of it than the gratification of intelligent curiosity.

If any one wants to exemplify the meaning of the word "fish" he cannot choose a better animal than a herring. The body, tapering to each end, is covered with thin, flexible scales, which are very easily rubbed off. The taper head, with its underhung jaw, is smooth and scaleless on the top; the large eye is partly covered by two folds of transparent skin, like eyelids—only immovable and with the slit between them vertical instead of horizontal; the cleft behind the gill cover is very wide, and, when the cover is raised, the large red gills which lie beneath it are freely exposed. The rounded back bears the single moderately long dorsal fin about its middle. The tail fin is deeply cleft, and on careful inspection small scales are seen to be continued from the body, on to both its upper and its lower lobes, but there is no longitudinal scaly fold on either of these. The belly comes to an edge, covered by a series of sharply-keeled bony shields between the throat and the vent; and behind the last is the anal fin, which is of the same length as the dorsal fin. There is a pair of fore-limbs, or pectoral fins, just behind the head; and a pair of hind-limbs, or ventral fins, are situated beneath the dorsal fin, a little behind a vertical line drawn from its front edge, and a long way in front of the vent. These fins have bony supports or rays, all of which are soft and jointed.

Like most fishes, the herring is propelled chiefly by the sculling action of the tail-fin, the rest serving chiefly to preserve the balance of the body, and to keep it from turning over, as it would do if left to itself, the back being the heaviest part of the fish.

The mouth of the herring is not very large, the gape extending back only to beneath the middle of the eye, and the teeth on the upper and lower jaws are so small as to be hardly visible. Moreover, when a live herring opens its mouth, or when the lower jaw of a dead herring is depressed artificially, the upper jaw, instead of remaining fixed and stationary, travels downwards and forwards in such a manner as to guard the sides of the gape. This movement is the result of a curious mechanical arrangement by which the lower jaw pulls upon the upper, and I suspect that it is useful in guarding the sides of the gape when the fish gulps the small living prey upon which it feeds.

The only conspicuous teeth, and they are very small, are disposed in an elongated patch upon the tongue, and in another such patch, opposite to these, on the fore part of the roof of the mouth. The latter are attached to a bone called the vomer, and are hence termed vomerine teeth. But, if the mouth of a herring is opened widely, there will be seen, on each side, a great number of fine, long, bristle-like processes, the pointed ends of which project forwards. These are what are termed the gill rakers, inasmuch as they are fixed, like the teeth of a rake, to the inner sides of those arches of bone on the outer sides of which the gills are fixed. The sides of the throat of a herring, in fact, are as it were cut by four deep and wide clefts which are separated by these gill arches, and the water which the fish constantly gulps in by the mouth flows through these clefts, over the gills and out beneath the gill covers, aërating the blood, and thus effecting respiration, as it goes. But since it would be highly inconvenient, and indeed injurious, were the food to slip out in the same way, these gill rakers play the part of a fine sieve, which lets the water strain off, while it keeps the food in. The gill rakers of the front arches are much longer than those of the hinder arches, and as each is stiffened by a thread of bone developed in its interior, while, at the same time, its sides are beset with fine sharp teeth, like thorns on a brier, I suspect that they play some part in crushing the life out of the small animals on which the herrings prey.

Between these arches there is, in the middle line, an opening which leads into the gullet. This passes back into a curious conical sac which is commonly termed the stomach, but which has more the character of a crop.

[1] A lecture delivered by Prof. Huxley at the National Fishery Exhibition, Norwich, April 21, 1881.

Coming off from the under side of the sac and communicating with it by a narrow opening, there is an elongated tubular organ, the walls of which are so thick and muscular that it might almost be compared to a gizzard. It is directed forwards, and opens by a narrow prominent aperture into the intestine, which runs straight back to the vent. Attached to the commencement of the intestine, there is a score or more of larger and shorter tubular organs which are called the pyloric cæca. These open into the intestine, and their apertures may be seen on one side of it, occupying an oval space, in the middle of which they are arranged three in a row.

The chief food of the herring consists of minute Crustacea, some of them allied to the shrimps and prawns, but the majority belonging to the same division as the common *Cyclops* of our fresh waters. These tenant many parts of the ocean in such prodigious masses that the water is discoloured by them for miles together, and every sweep of a fine net brings up its tens of thousands.

Everybody must have noticed the silvery air-bladder of the herring, which lies immediately under the backbone, and stretches from close to the head to very near the vent, being wide in the middle and tapering off to each end. In its natural state, it is distended with air; and, if it is pricked, the elastic wall shrinks and drives the air out, as if it were an indiarubber ball. When the connexions of this air-bladder are fully explored it turns out to be one of the most curious parts of the organisation of the whole animal.

In the first place, the pointed end of the sac or crop into which the gullet is continued runs back into a very slender duct which turns upwards and eventually opens into the middle of the air-bladder. The canal of this duct is so very small and irregularly twisted, that, even if the air-bladder is squeezed, the air does not escape into the sac. But, if air is forced into the sac by means of a blowpipe, the air passes without much difficulty the other way, and the air-bladder becomes fully distended. When the pressure is removed, however, the air-bladder diminishes in size to a certain extent, showing that the air escapes somewhere. And if the blowing up of the air-bladder is performed while the fish is under water, a fine stream of air-bubbles may be seen to escape close to the vent. Careful anatomical investigation, in fact, shows that the air-bladder does not really end at the point where its silvery coat finishes, but that a delicate tube is continued thence to the left side of the vent, and there ends by an opening of its own.

Now the air-bladder of all fishes is, to begin with, an outgrowth from the front part of the alimentary canal, and there are a great many fishes in which, as in the herring, it remains throughout life in permanent communication with the gullet. But it is rare to find the duct so far back as in the herring; and, at present, I am not aware that the air-bladder opens externally in any fishes except the herring and a few of its allies.

There is a general agreement among fishermen that herrings sometimes make a squeaking noise when they are freshly taken out of the water. I have never heard this sound myself, but there is so much concurrent testimony to the fact that I do not doubt it; and it occurs to me that it may be produced when the herrings are quickly brought up from some depth by means of this arrangement. For under these circumstances the air, which the air-bladder contains, expands to such a degree, on being relieved from the pressure of the water, that deep-sea fishes with a closed air-bladder which are brought to the surface rapidly are sometimes fairly turned inside out by the immense distension, or even bursting, of the air-bladder. If the same thing should happen to the herring the like misfortune would not befall it, for the air would be forced out of the opening in question, and might readily enough produce the squeak which is reported. The common Loach[1] is said to produce a piping sound by expelling the air which this fish takes into its intestine for respiratory purposes.

At the opposite end of the air-bladder there is an even more curious arrangement. The silvery coat of the air-bladder ends in front just behind the head. But the air-bladder itself does not terminate here. Two very fine canals, each of which is not more than a two-hundredth of an inch in diameter, though it is surrounded by a relatively thick wall of cartilage, pass forward, one on each side, from the air-bladder to the back of the skull. The canals enter the walls of the skull, and then each divides into two branches. Finally, each of these two dilates into a bag which lies in a spheroidal chamber of corresponding size and form; and, in consequence of the air which they contain, these bags may be seen readily enough shining through the side walls of the skull, the bone of which has a peculiar structure where it surrounds them. Now these two bags, which constitute the termination of the air-bladder on each side, are in close relation with the organ of hearing. Indeed, a process of that organ projects into the front chamber on each side, and is separated by only a very delicate partition from the terminal sac of the air-bladder. Any vibrations of the air in these sacs, or any change in the pressure of the air in them, must thus tell upon the hearing apparatus.

There is no doubt about the existence of these structures which, together with the posterior opening of the air-bladder, were most accurately described, more than sixty years ago, by the eminent anatomist Weber, but I am afraid we are not much wiser regarding their meaning than we were when they were first made known. In fishes in general, there can be little doubt that the chief use of the air-bladder is to diminish the specific gravity of the fish and, by rendering its body of nearly the same weight as so much water, to render the business of swimming easier. In those fishes in which the passage of communication between the air-bladder and the alimentary canal is closed, the air is no doubt secreted into the air-bladder by its vessels, which are often very abundant. In the herring, the vessels of the air-bladder are very scanty; and it seems probable that the air is swallowed and forced into the air-bladder just as the loach swallows air and drives it into its intestine. And, as I have already suggested, it may be that the narrow posterior canal which leads from the air-bladder to the exterior is a sort of safety-valve allowing the air to escape, when the fish, rapidly ascending or descending, alters the pressure of the water upon the contained air.

This hypothesis may be put forward with some show of probability, but I really find it difficult to suggest anything with respect to the physiological meaning of the connection between the air-bladder and the ear. Nevertheless such an elaborate apparatus must have some physiological importance; and, this conclusion is strengthened by the well-known fact that there are a great many fishes in which the air-bladder and the ear become connected in one way or another. In the carp tribe, for example, the front end of the air-bladder is connected by a series of little bones with the organ of hearing, which is, as it were, prolonged backwards to meet these bones in the hinder end of the skull. But here, the air-bladder, which is very large, may act as a resonator; while, in the herring, the extreme narrowness of the passages which connect the air-bladder with the ear renders it difficult to suppose that the organ can have any such function.

In addition to the singular connection of the ear with the exterior by the roundabout way of the air-bladder, there are membranous spaces in the walls of the skull by which vibrations can more directly reach the herring's ear. And there is no doubt that the fish is very sensitive

[1] See Müller, "Ueber Fische welche Töne von sich geben," *Archiv für Physiologie*, 1857, p. 267. The herring is not mentioned in Müller's list of vocal fishes.

to such vibrations. In a dark night, when the water is phosphorescent or, as the fishermen say, there is plenty of "merefire," it is a curious spectacle to watch the effect of sharply tapping the side of the boat as it passes over a shoal. The herrings scatter in all directions, leaving streaks of light behind them, like shooting stars.

The herring, like other fishes, breathes by means of the gills—the essential part of which consists of the delicate, highly-vascular filaments, which are set in a double row on the outer faces of each of the gill arches. The venous blood which returns from all parts of the body to be collected in the heart, is pumped thence into the gills, and there exchanges its excess of carbonic acid gas for the gaseous oxygen which is dissolved in sea-water. The freedom of passage of the water, and the great size and delicacy of the gills, facilitate respiration when the fish is in its native element; but the same peculiarities permitting of the rapid drying and coherence of the gills, and thus bringing on speedy suffocation, render its tenure of life, after removal from the water, as short as that of any fish. It may be observed, in passing, that the wide clefts behind the gill-covers of the herring have some practical importance, as the fish, thrusting its head through the meshes of the drift-net, is caught behind them and cannot extricate itself. In the herring, the upper end of the last gill cleft is not developed into a sac or pouch, such as we shall find in some of its near neighbours.

The only other organs of the herring, which need be mentioned at present, are the milt and roe, found in the male and female herring respectively.

These are elongated organs attached beneath the air-bladder, which lie, one on each side of the abdominal cavity, and open behind the vent by an aperture common to the two. The spermatic fluid of the male is developed in the milt and the eggs of the female in the roe. These eggs, when fully formed, measure from one-sixteenth to one-twenty-fifth of an inch in diameter; and, as, in the ripe female, the two roes or ovaries stretch from one end of the abdominal cavity to the other, occupying all the space left by the other organs, and distending the cavity, the number of eggs which they contain must be very great. Probably 10,000 is an under-estimate of the number of ripe eggs shed in spawning by a moderate-sized female herring. But I think it is safer than the 30,000 of some estimates, which appear to me to be made in forgetfulness of the very simple anatomical considerations that the roe consists of an extensive vascular framework as well as of eggs; and, moreover, that a vast number of the eggs which it contains remain immature, and are not shed at the time of spawning.

In this brief account of the structure of the herring I have touched only on those points which are peculiarly interesting, or which bear upon what I shall have to say by and by. An exhaustive study of the fish from this point of view alone would require a whole course of lectures to itself.

The herring is a member of a very large group of fishes spread over all parts of the world, and termed that of the *Clupeidæ*, after *Clupea*, the generic name of the herring itself. Our herring, the *Clupea harengus*, inhabits the White Sea and perhaps some parts of the Arctic Ocean, the temperate and colder parts of the Atlantic, the North Sea, and the Baltic, and there is a very similar, if not identical, species in the North Pacific. But it is not known to occur in the seas of southern Europe, nor in any part of the intertropical ocean, nor in the southern hemisphere.

There are four British fishes which so closely resemble herrings, externally and internally, that, though practical men may not be in any danger of confounding them, scientific zoologists have not always succeeded in defining their differences. These are the Sprat, the Allice and Twaite Shads, and the Pilchard.

The sprat comes nearest; indeed young herrings and sprats have often been confounded together, and doubts have been thrown on the specific distinctness of the two. Yet if a sprat and a young herring of the same size are placed side by side, even their external differences leave no doubt of their distinctness. The sprat's lower jaw is shorter; the shields in the middle of the belly have a sharper keel, whence the ventral edge is more like a saw; and the ventral fin lies vertically under the front edge of the dorsal fin, or even in front of it; while in the herring, though the position of the ventral fin varies a little, it lies more or less behind the front margin of the dorsal fin. The anal fin is of the same length as the dorsal, in the herring, longer than the dorsal in the sprat. But the best marks of distinction are the absence of vomerine teeth in the sprat, and the smaller number of pyloric cæca, which do not exceed nine, their openings being disposed in a single longitudinal series.

Shads and pilchards have a common character by which they are very easily distinguished from both sprat and herring. There is a horizontal fold of scaly skin on each side of the tail above and below the middle line. Moreover they have no teeth in the inside of the mouth, and their pyloric cæca are very numerous—a hundred or more—their openings being disposed five or six in a row.

The shads have a deep narrow notch in the middle line of the upper jaw, which is absent in the pilchard. The intestine of the shad is short and straight, like that of the herring; while that of the pilchard is long and folded several times upon itself.

Both of these fishes, again, possess a very curious structure, termed an accessory branchial organ, which is found more highly developed in other fishes of the herring family, and attains its greatest development in a fresh-water fish, the *Heterotis*, which inhabits the Nile. This organ is very rudimentary in the shad (in which it was discovered by Gegenbaur[1]), but it is much larger in the pilchard, in which, so far as I know, it has not heretofore been noticed. In *Chanos* and several other Clupeoid fishes it becomes coiled upon itself, and in *Heterotis* the coiled organ makes many turns. The organ is commonly supposed to be respiratory in function; but this is very doubtful.

Herrings which have attained maturity and are distended by the greatly enlarged milt or roe are ready to shed the contents of these organs or, as it is said to spawn. In 1862, we found a great diversity of opinion prevailed as to the time at which this operation takes place, and we took a great deal of trouble to settle the question, with the result which is thus stated in our Report:—

"We have obtained a very large body of valuable evidence on this subject, derived partly from the examination of fishermen and of others conversant with the herring fishery; partly from the inspection of the accurate records kept by the fishery officers at different stations, and partly from other sources; and our clear conclusion from all this evidence is, that the herring spawns at two seasons of the year, in the spring and in the autumn. We have hitherto met with no case of full or spawning herrings being found, in any locality, during what may be termed the solstitial months, namely June and December; and it would appear that such herrings are never (or very rarely) taken in May or the early part of July, in the latter part of November, or the early part of January. But a spring spawning certainly occurs in the latter part of January, in February, in March, and in April; and an autumn spawning in the latter part of July, in August, September, October, and even as late as November. Taking all parts of the British coast together, February and March are the great months for the spring spawning, and August and September for the autumn spawning. It is not at all likely that the same fish spawn twice in the year; on the contrary, the spring and the autumn shoals are probably perfectly distinct; and if the herring, according to the hypothesis advanced above, come to maturity

[1] "Ueber das Kopfskelet von *Alepocephalus rostratus*," *Morphologisches Jahrbuch*, Bd. iv., Suppl. 1878.

in a year, the shoals of each spawning season would be the fry of the twelvemonth before. However, no direct evidence can be adduced in favour of this supposition, and it would be extremely difficult to obtain such evidence." [1]

I believe that these conclusions, confirmatory of those of previous careful observers [2] are fully supported by all the evidence which has been collected, and the fact that this species of fish has two spawning seasons, one in the hottest and one in the coldest months of the year, is very curious.

Another singular circumstance connected with the spawning of the herring is the great variety of the conditions, apart from temperature, to which the fish adapts itself in performing this function. On our own coasts, herrings spawn in water of from ten to twenty fathoms, and even at greater depths, and in a sea of full oceanic saltness. Nevertheless herrings spawn just as freely, not only in the narrows of the Baltic, such as the Great Belt, in which the water is not half as salt as it is in the North Sea and in the Atlantic, but even in such long inlets as the Schlei in Schleswig, the water of which is quite drinkable and is inhabited by freshwater fish. Here the herrings deposit their eggs in two or three feet of water; and they are found, along with the eggs of freshwater fish, sticking in abundance to such freshwater plants as *Potamogeton*.

Nature seems thus to offer us a hint as to the way in which a fish like the shad, which is so closely allied to the herring, has acquired the habit of ascending rivers to deposit its eggs in purely fresh water.

If a full female herring is gently squeezed over a vessel of sea-water, the eggs will rapidly pour out and sink to the bottom, to which they immediately adhere with so much tenacity that, in half an hour, the vessel may be inverted without their dropping out. When spawning takes places naturally the eggs fall to the bottom and attach themselves in a similar fashion. But, at this time, the assembled fish dart wildly about, and the water becomes cloudy with the shed fluid of the milt. The eggs thus become fecundated as they fall, and the development of the young within the ova sticking to the bottom commences at once.

The first definite and conclusive evidence as to the manner in which herring spawn is attached and becomes developed that I know of, was obtained by Prof. Allman and Dr. MacBain in 1862,[3] in the Firth of Forth. By dredging in localities in which spent herring were observed on the 1st of March, Professor Allman brought up spawn in abundance at a depth of fourteen to twenty-one fathoms. It was deposited on the surface of the stones, shingle, and gravel, and on old shells and coarse shell-sand, and even on the shells of small living crabs and other crustacea, adhering tenaciously to whatever it had fallen on. No spawn was found in any other part of the Forth; but it continued to be abundant on both the east and the west sides of the Isle of May up to the 13th of March, at which time the incubation of the ovum was found to be completed in a great portion of the spawn, and the embryos had become free. On the 25th scarcely a trace of spawn could be detected, and nearly the whole of the adult fish had left the Forth.

Prof. Allman draws attention to the fact "that the deposit of spawn, as evidenced by the appearance of spent herrings, did not take place till about sixty-five days after the appearance of the herring in the Firth," and arrives at the conclusion that "the incubation probably continues during a period of between twenty-five to thirty days," adding however that the estimate must for the present be regarded as only approximative. It was on this and other evidence that we based our conclusion that the eggs of the herring "are hatched in at most from two to three weeks after deposition."

Within the last few years a clear light has been thrown upon this question by the labours of the West Baltic Fishery Commission, to which I have so often had occasion to refer.[1] It has been found that artificial fecundation is easily practised, and that the young fish may be kept in aquaria for as long as five months. Thus, a great body of accurate information, some of it of a very unexpected character, has been obtained respecting the development of the eggs, and the early condition of the young herring.

It turns out that, as is the case with other fishes, the period of incubation is closely dependent upon warmth. When the water has a temperature of 53° Fahrenheit, the eggs of the herring hatch in from 6—8 days; the average being seven days. And this is a very interesting fact when we bear in mind the conclusion to which the inquiries of the Dutch meteorologists, and, more lately, those of the Scottish Meteorological Society appear to tend, namely, that the shoals prefer water of about 55°. At 50° Fahrenheit, the period of incubation is lengthened to eleven days; at 46° to fifteen days; and at 38° it lasts forty days. As the Forth is usually tolerably cool in the month of March, it is probable that Prof. Allman's estimate comes very near the truth for the particular case which he investigated.

The young, when they emerge from the egg, are from one-fifth to one-third of an inch in length, and so extremely unlike the adult herring that they may properly be termed larvæ. They have enormous eyes and an exceedingly slender body, with a yelk bag protruding from its forepart. The skeleton is in a very rudimentary condition; there are no ventral fins; and instead of separate dorsal, caudal, and anal fins, there is one continuous fin extending from the head along the back, round the tail, and then forwards to the yelk bag. The intestine is a simple tube, ciliated internally; there is no air-bladder, and no branchiæ are yet developed. The heart is a mere contractile vessel, and the blood is a clear fluid without corpuscles. At first the larvæ do not feed, but merely grow at the expense of the yelk, which gradually diminishes.

Within three or four days after hatching, the length has increased by about half the original dimensions, the yelk has disappeared, the cartilaginous skeleton appears, and the heart becomes divided into its chambers; but the young fish attains nearly double its first length before blood corpuscles are visible.

By the time the larva is two-thirds of an inch long (a length which it attains one month after hatching), the primitive median fin is separated into dorsal, caudal, and anal divisions, but the ventral fins have not appeared. About this period the young animal begins to feed on small crustacea; and it grows so rapidly that, at two months, it is $1\frac{1}{4}$ inch long, and, at three months, has attained a length of about two inches.

Nearly up to this stage the elongated scaleless little fish retains its larval proportions; but, in the latter part of the third month, the body rapidly deepens, the scales begin to appear, and the larva passes into the "imago" state —that is, assumes the form and proportions of the adult, though it is not more than two inches long. After this, it goes on growing at the same rate (11 millimetres, or nearly half an inch) per month, so that, at six months old, it is as large as a moderate-sized sprat.

The well-known "whitebait" of the Thames consists,

[1] "Report of the Royal Commission on the operation of the Acts relating to Trawling for Herrings on the Coast of Scotland (1863)," p. 28.

[2] Brandt and Ratzeburg, for example, in 1833 strongly asserted that the herring has two spawning seasons.

[3] "Report of the Royal Commission on the Operation of the Acts relating to Trawling for Herring on the Coast of Scotland, 1863."

[1] See the four valuable memoirs, Kupffer, "Ueber Laichen und Entwickelung des Herings in der westlichen Ostsee"; *Idem*, "Die Entwickelung des Herings im Ei"; Meyer, "Beobachtungen über den Wachsthum des Herings"; Heincke, "Die Varietäten des Herings," which are contained in the *Jahresbericht der Commission in Kiel für* 1874-75-76 — 1878. Widegren's essay "On the Herring," 1871, translated from the Danish in U.S. Commission Reports, 1873—75, also contains important information.

so far as I have seen, almost exclusively of herrings, under six months old, and as the average size of whitebait increases, from March and April onwards, until they become suspiciously like sprats in the late summer, it may be concluded that they are the progeny of herrings which spawned, early in the year, in the neighbourhood of the estuary of the Thames, up which these dainty little fish have wandered. Whether it is the general habit of young herring, even of those which are spawned in deep water, to migrate into the shallow parts of the sea, or even into completely fresh waters, when such are accessible, is unknown.

In the Report on Trawling (1863) we observe :—

"It is extremely difficult to obtain any satisfactory evidence as to the length of time which the herring requires to pass from the embryonic to the adult or *full* condition. Of the fishermen who gave any opinion on this subject, some considered that a herring takes three, and others that it requires seven, years to attain the full or spawning condition ; others frankly admitted that they knew nothing about the matter ; and it was not difficult, by a little cross-examination, to satisfy ourselves that they were all really in this condition, however strongly they might hold by their triennial or septennial theories. Mr. Yarrell and Mr. Mitchell suppose with more reason that herring attain to full size and maturity in about eighteen months.

"It does not appear, however, that there is any good evidence against the supposition that the herring reaches its spawning condition in one year. There is much reason to believe that the eggs are hatched in, at most, from two to three weeks after deposition, and that in six to seven weeks more (that is at most ten weeks from the time of laying the eggs) the young have attained three inches in length. Now it has been ascertained that a young smolt may leave a river and return to it again in a couple of months increased in bulk eight or tenfold, and as a herring lives on very much the same food as a smolt, it appears possible that it should increase in the same rapid ratio. Under these circumstances nine months would be ample time for it to enlarge from three to ten or eleven inches in length. It may be fairly argued, however, that it is not very safe to reason analogically from the rate of growth of one species of fish to that of another ; and it may be well to leave the question whether the herring attains its maturity in twelve, fifteen, or sixteen months open, in the tolerably firm assurance that the period last named is the maximum."

On comparing these conclusions with the results of the careful observations of the Baltic Commissioners, it appears that we somewhat over-estimated the rate of growth of the young herring, and that the view taken by Yarrell and Mitchell is more nearly correct. For supposing that the rate of growth after six months continues the same as before, a herring twelve months old will be nearly six inches long, and at eighteen months eight or nine inches. But full herrings may be met with little more than seven inches long, and they are very commonly found not more than nine inches in length.[1]

Fishermen distinguish four states of the herring. Fry or sile, when not larger than sprats ; maties, when larger than this, with undeveloped roe or milt ; full fish, with largely developed roe or milt ; and spent or shotten fish, which have recently spawned.

Herring fry of the size of sprats are distinguished from full fish not merely by their size, but in addition, by the very slight development of the milt or roe, and by the accumulation of fat in the abdominal cavity. Bands of fat are found in the mesentery alongside the intestine, and filling up the interspaces between the pyloric cæca.

[1] Ljungman ("Preliminary Report on Herrings and Herring Fisheries on the West Coast of Sweden," translated in U.S. Commision Report, 1873-5) speaks of full herrings ready to spawn only 100-110 mm. (4 to 4½ in.) long, as observed by himself.

Maties (the name[1] of which is a corruption of the Dutch word for a maiden) resemble the fry in these particulars ; but, if they are well fed, the deposit of fatty and other nutritive matter takes place, not only about the abdominal viscera, but also beneath the skin and in the interstices of the flesh. Indeed, when nourishment is abundant, this infiltration of the flesh with fat may go so far that the fish cannot readily be preserved and must be eaten fresh. The singularly delicate Loch Fyne herrings are in this condition early in the season. When the small crustaceans, on which the maties chiefly feed, are extremely abundant the fish gorge themselves with them to such an extent that the conical crop becomes completely distended, and the Scotch fishermen give them the name of "gut-pock herrings," as much as to say pouch-gutted fish, and an absurd notion is current that these herrings are diseased. However, the "gut-pock" herrings differ from the rest only in having their pouch full instead of empty, as it commonly is.

As the fish passes from the matie to the full condition, the milt and roe begin to grow at the expense of the nutriment thus stored up ; and, as these organs become larger and occupy more and more space in the abdominal cavity, the excess of nutritious substance is transferred to them. The fatty deposit about the intestine and pyloric cæca gradually disappears and the flesh becomes poorer. It would appear that by degrees the fish cease to feed at all. At any rate, there is usually no food in the stomach of a herring which approaches maturity. In all these respects there is the closest resemblance between the history of the herring and that of other fishes such as the salmon—the parr correspnding to the herring fry or sile, the grilse and the "clean fish" of larger size to the maties.

At length spawning takes place, the accumulated nutrition, transformed into eggs or spermatic fluid, is expelled, and the fish is left in that lean and depauperated state which makes a "shotten herring" proverbial. In this condition it answers to the salmon "kelt," and the milt or roe are now shrunk and flaccid and can be blown up with air like empty bags. If the spent fish escapes its myriad enemies, it doubtless begins to feed again and once more passes into the matie state in preparation for the next breeding season. But the nature of this process of recuperation has yet to be investigated.

When they have reached the matie stage, the herrings, which are at all times gregarious, associate together in conspicuous assemblages, which are called shoals. These are sometimes of prodigious extent—indeed eight or nine miles in length, two or three in breadth, with an unknown depth, are dimensions which are credibly asserted to be sometimes attained. In these shoals the fish are closely packed, like a flock of sheep straying slowly along a pasture, and it is probably quite safe to assume that there is at least one fish for every cubic foot of water occupied by the shoal. If this be so, every square mile of such a shoal, supposing it to be three fathoms deep, must contain more than 500,000,000 herrings. And when it is considered that many shoals approach the coasts, not only of our own islands, but of Scandinavia and the Baltic, and of Eastern North America, every spring and autumn, the sum total of the herrings which people our seas surpasses imagination.

If you read any old and some new books on the natural history of the herring, you will find a wonderful story about the movements of these shoals. How they start from their home in the Polar Seas, and march south as a great armada which splits into minor divisions—one destined to spawn on the Scandi-

[1] "Halecum intestina, non modo multa gaudere obesitate, sed et totum corpus eo adeo esse impletum ut aliquando, cum discinditur, pinguedo ex cultro defluat, et præsertim eo quidem tempore ubi halecum lactes aut ova crescere primum incipiunt, unde nostrates eos *Maatgens-Haringen* dicere solent."—A. v. Leeuwenhoek, "Arcana Naturæ," Ep. xcvii. (1696).

Leeuwenhoek also mentions having heard of "gut pock" herrings from Scotch fishermen.

navian, and one on our own shores; and how, having achieved this spawning raid, the spent fish make their way as fast as they can back to their Arctic refuge, there to repair their exhausted frames in domestic security. This story was started in the last century, and was unfortunately adopted and disseminated by our countryman Pennant. But there is not the least proof that anything of the kind takes place, and the probabilities are wholly against it. It is, for example, quite irreconcilable with the fact that herring are found in cods' stomachs all the year round. And the circumstance to which I have already adverted, that practised eyes distinguish local breeds of herrings, though it does not actually negative the migration hypothesis, is very much against it. The supposition that the herring spawn in the north in the early spring, and in the south in the autumn, fitted very well into the notion that the vanguard of the migrating body of herrings occupied the first spawning ground it reached, and obliged the rest of the horde to pass on. But, as a matter of fact, the northern herrings, like the southern, have two spawning times; or perhaps it would be more correct to say that the spawning time extends from autumn to spring, and has two maxima—one in August-September, and one in February-March.

Finally, there is no evidence that herrings are to be met with in the extreme north of their range, at other times, or in greater abundance, than they are to be found elsewhere.

In the matter of its migration, as in other respects, the herring compares best with the salmon. The ordinary habitation of both fishes is no doubt the moderately deep portion of the sea. It is only as the breeding time draws near that the herrings (not yet advanced beyond the matie state) gather together towards the surface and approach the land in great shoals for the purpose of spawning in relatively or absolutely shallow water. In the case of the herring of the Schlei we have almost the connecting link between the exclusively marine ordinary herring and the river ascending salmon.

The records of the herring fisheries are, for the most part, neither very ancient nor (with the exception of those of the Scotch Fishery Board) very accurately kept; and, from the nature of the case, they can only tell us whether the fish in any given year were readily taken or not, and that may have very little to do with the actual strength of the shoals.

However, there is historical evidence that, long before the time of Henry the First, Yarmouth was frequented by herring fishers. This means that, for eight centuries, herrings have been fished on the English coast, and I cannot make out, taking one year with another, in recent times, that there has been any serious fluctuation in their numbers. The number captured must have enormously increased in the last two centuries, and yet there is no sign of diminution of the shoals.

In 1864, we had to listen to dolorous prophecies of the coming exhaustion of the Scotch herring fisheries. The fact that the returns showed no falling off was ascribed to the improvement of the gear and methods of fishing, and to the much greater distances to which the fishermen extend their operations. Yet what has really happened? The returns of subsequent years prove, not only that the average cure of the decade 1869-78 was considerably greater than that of the previous decade, but that the years 1874 and 1880 are absolutely without parallel in the annals of the Scotch herring fishery, a million barrels having been cured in the first of these years, and a million and a half in 1880. In the decade 1859-68, the average was 670,000 barrels, and the highest 830,000.

In dealing with questions of biology, *à priori* reasoning is somewhat risky, and if any one tells me "it stands to reason" that such and such things must happen, I generally find reason to doubt the safety of his standing.

It is said that "it stands to reason" that destruction on such a prodigious scale as that effected by herring fishers must tell on the supply. But again let us look at the facts. It is said that 2,500,000,000, or thereabouts, of herrings are every year taken out of the North Sea and the Atlantic. Suppose we assume the number to be 3,000,000,000 so as to be quite safe. It is a large number undoubtedly, but what does it come to? Not more than that of the herrings which may be contained in one shoal, if it covers half a dozen square miles—and shoals of much larger size are on record. It is safe to say that, scattered through the North Sea and the Atlantic, at one and the same time, there must be scores of shoals, any one of which would go a long way towards supplying the whole of man's consumption of herrings. I do not believe that all the herring fleets taken together destroy 5 per cent. of the total number of herrings in the sea in any year, and I see no reason to swerve from the conviction my colleagues and I expressed in our Report, that their destructive operations are totally insignificant when compared with those which, as a simple calculation shows, must regularly and normally go on.

Suppose that every mature female herring lays 10,000 eggs, that the fish are not interfered with by man, and that their numbers remain approximately the same year after year, it follows that 9998 of the progeny of every female must be destroyed before they reach maturity. For if more than two out of the 10,000 escape destruction, the number of herrings will be proportionately increased. Or in other words, if the average strength of the shoals which visit a given locality is to remain the same year by year, many thousand times the number contained in those shoals must be annually destroyed. And how this enormous amount of destruction is effected will be obvious to any one who considers the operations of the fin-whales, the porpoises, the gannets, the gulls, the codfish, and the dogfish, which accompany the shoals and perennially feast upon them; to say nothing of the flat-fish, which prey upon the newly-deposited spawn; or of the mackerel, and the innumerable smaller enemies which devour the fry in all stages of their development. It is no uncommon thing to find five or six—nay, even ten or twelve—herrings in the stomach of a codfish,[1] and, in 1863, we calculated that the whole take of the great Scotch herring fisheries is less than the number of herrings which would in all probability have been consumed by the codfish captured in the same waters if they had been left in the sea.[2]

Man, in fact, is but one of a vast co-operative society of herring-catchers, and the larger the share he takes, the less there is for the rest of the company. If man took none, the other shareholders would have a larger dividend, and would thrive and multiply in proportion, but it would come to pretty much the same thing to the herrings.

As long as the records of history give us information, herrings appear to have abounded on the east coast of the British Islands, and there is nothing to show, so far as I am aware, that, taking an average of years, they were ever either more or less numerous than they are at present. But in remarkable contrast with this constancy, the shoals of herrings have elsewhere exhibited a change capriciousness—visiting a given locality for many years in great numbers, and then suddenly disappearing. Several well-marked examples of this fickleness are recorded on the west coast of Scotland; but the most remarkable is that furnished by the fisheries of Bohüslan, a province which lies on the south-western shore of the Scandinavian peninsula. Here a variety known as the "old" or

[1] In his valuable Report on the Salt Water Fisheries of Norway (1877), Prof. Sars expresses the belief that full-grown codfishes feed chiefly, if not exclusively, on herrings.

[2] In 1879 rather more than 5,000,000 cod, ling, and hake, were taken by the Scottish fishermen. Allowing each only two herrings a day, these fishes would have consumed more than three thousand five hundred million of herrings in a year. As to the Norwegian fisheries, 20,000,000 codfishes are said to be taken annually by the Lofoden fishermen alone.

"great" herring, after being so extremely abundant, for about sixty years, as to give rise to a great industry, disappeared in the year 1808, as suddenly as they made their appearance, and have not since been seen in any number.

The desertion of their ordinary grounds by the herring has been attributed to all imaginable causes, from fishing on a Sunday to the offence caused to the fish by the decomposing carcases of their brethren, dropped upon the bottom out of the nets. The truth is that absolutely nothing is known on the subject; and that little is likely to be known, until careful and long-continued meteorological and zoological observations have furnished definite information respecting the changes which take place in the temperature of the sea, and the distribution of the pelagic crustacea which constitute the chief food of the herring shoals. The institution of systematic observations of this kind is an object of international importance, towards the attainment of which the British, Scandinavian, Dutch, and French Governments might wisely make a combined effort.

A great fuss has been made about trawlers working over the spawning grounds of the herring. "It stands to reason," we were told, that they must destroy an immense quantity of the spawn Indeed this looked so reasonable, that we inquired very particularly into a case of the alleged malpractice which was complained of on the east coast of Scotland, near Pittenweem. Off this place, there is a famous spawning ground known as the Traith hole, and we were told that the trawlers worked vigorously over the spot immediately after the herring had deposited their spawn. Of course our first proceeding was to ask the trawlers why they took the trouble of doing what looked like wanton mischief. And their answer was reasonable enough. It was to catch the prodigious abundance of flat-fish which were to be found on the Traith at that time. Well, then, why did the flat-fish congregate there? Simply to feed on herring eggs, which seem to be a sort of flat-fishes' caviare. The stomachs of the flat-fish brought up by the trawl were, in fact, crammed with masses of herring eggs.

Thus every flat-fish caught by the trawl was an energetic destroyer of herring arrested in his career. And the trawling, instead of injuring the herring, captured and removed hosts of their worst enemies. That is how "it stood to reason" when one got to the bottom of the matter.

I do not think that any one who looks carefully into the subject will arrive at any other conclusion than that reached by my colleagues and myself: namely, that the best thing for Governments to do in relation to the herring fisheries, is to let them alone, except in so far as the police of the sea is concerned. With this proviso, let people fish how they like, as they like, and when they like. At present, I must repeat the conviction we expressed so many years ago, that there is not a particle of evidence that anything man does has an appreciable influence on the stock of herrings. It will be time to meddle, when any satisfactory evidence that mischief is being done is produced

NOTES

THE fifty-first Annual Meeting of the British Association for the Advancement of Science will commence at York on Wednesday, August 31, 1881. The President-Elect is Sir John Lubbock, Bart, M.P., F.R.S. Vice-Presidents Elect: His Grace the Archbishop of York, D.D., F.R.S.; the Right Hon. the Lord Mayor of York; the Right Hon. Lord Houghton, F.R.S.; the Ven. Archdeacon Creyke, M.A.; the Hon. Sir W. R. Grove, F.R.S.; Prof. G. G. Stokes, Sec. R.S.; Sir John Hawkshaw, C.E., F.R.S.; Allen Thomson, M.D., F.R.S. L. and E.; Prof. Allman, M.D., F.R.S. L. and E. General Secretaries: Capt. Douglas Galton, C.B., D.C.L., F.R.S.; Philip Lutley Sclater, Ph.D., F.R.S. Acting Secretary: George Griffith, M.A., F.C.S., Harrow; General Treasurer: Prof. A. W. Williamson, F.R.S., University College, London, W.C. Local Secretaries: Rev. Thomas Adams, M.A.; Tempest Anderson, M.D., B.Sc., York. Local Treasurer: W. W. Wilberforce, York. The Sections are the following:—A.—Mathematical and Physical Science.—President: Prof. Sir William Thomson, F.R.S. L. and E. Vice-Presidents.—Prof. J. C. Adams, F.R.S.; T. Archer Hirst, Ph.D., V.P.R.S. Secretaries: Prof. W. E. Ayrton; Oliver J. Lodge, D.Sc.; Donald McAlister, B.A., B.Sc. (Recorder). B.—Chemical Science.—President: Prof. A. W. Williamson, For. Sec. R.S., V.P.C.S. Vice-Presidents: F. A. Abel, C.B., F.R.S.; Prof. Odling, F.R.S. Secretaries: Harold B. Dixon, M.A.; P. Phillips-Bedson, D.Sc. (Recorder). C.—Geology.—President: Andrew Crombie Ramsay, LL.D., F.R.S., Director-General of the Geological Survey of the United Kingdom and of the Museum of Practical Geology. Vice-Presidents: Prof. Prestwich, F.R.S.; Prof. W. C. Williamson, F.R.S.; Secretaries: W. Topley, F.G.S. (Recorder); W. Whitaker, F.G.S. D.—Biology.—President: Richard Owen, C.B., F.R.S. Vice-Presidents: Prof. W. H. Flower, F.R.S.; Prof. J. S. Burdon Sanderson, F.R.S. Secretaries: G. W. Bloxam, M.A., F.L.S.; W. L. Distant; W. A. Forbes, F.Z.S.; Prof. M'Nab, M.D.; John Priestley; Howard Saunders, F.L.S., F.Z.S. Department of Zoology and Botany.—Richard Owen, C.B., F.R.S. (President), will preside. Secretaries: Prof. M'Nab, M.D. (Recorder); Howard Saunders, F.L.S., F.Z.S. Department of Anthropology.—Prof. W. H. Flower, F.R.S. (Vice-President), will preside. Secretaries: G. W. Bloxam, M.A., F.L.S. (Recorder); W. L. Distant. Department of Anatomy and Physiology.—Prof. J. S. Burdon Sanderson, F.R.S. (Vice-President), will preside. Secretaries: John Priestley (Recorder); W. A. Forbes, F.Z.S. E.—Geography.—President: Sir J. D. Hooker, K.C.S.I., C.B., F.R.S. Vice-Presidents: Francis Galton, F.R.S.; Prof. Sir C. Wyville Thomson, F.R.S. L. & E. Secretaries: H. W. Bates, Assist.-Sec.R.G.S., F.L.S.; E. C. Rye, Librarian R.G.S., F.Z.S. (Recorder). F.—Economic Science and Statistics.—President: The Right Hon. M. E. Grant Duff, M.P., F.R.S. Vice-Presidents: Sir George Campbell, K.C.S.I., M.P.; James Heywood, F.R.S. Secretaries: Constantine Molloy (Recorder); J. F. Moss. G.—Mechanical Science.—President: Sir W. G. Armstrong, C.B., F.R.S. Vice Presidents: W. H. Barlow, F.R.S., Pres.Inst.C.E.; C. W. Siemens, D.C.L., F.R.S. Secretaries: A. T. Atchison, M.A. (Recorder); H. Trueman Wood, B.A. Tickets for the meeting may be obtained of the Local Secretaries at York, and at the Office of the Association, 22, Albemarle Street, London, W.; or on application by letter, from August 17 to August 24, to the General Treasurer, Prof. A. W. Williamson, British Association, University College, London, W.C. The First General Meeting will be held on Wednesday, August 31, at 8 p.m. precisely, when A. C. Ramsay, F.R.S., V.P.G.S., Director-General of the Geological Survey of the United Kingdom, and of the Museum of Practical Geology, will resign the chair, and Sir John Lubbock, Bart., M.P., F.R.S., President-Elect, will assume the presidency, and deliver an address. On Thursday evening, September 1, at 8 p.m., a *soirée;* on Friday evening, September 2, at 8.30 p.m., a discourse by T. H. Huxley, LL.D., Sec.R.S., Professor of Natural History in the Royal School of Mines; on Monday evening, September 5, at 8.30 p.m., a discourse by W. Spottiswoode, D.C.L., LL.D., President of the Royal Society; on Tuesday evening, September 6, at 8 p.m., a *soirée;* on Wednesday, September 7, the concluding general meeting will be held at 2.30 p.m. No report, paper, or abstract, can be inserted in the Report of the Association unless it is given in before the conclusion of the meeting. Excursions to places of interest in the neighbourhood of York